SOUTHERN CALIFORNIA EDISON
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SCE Energy Storage Experience

TSP & ISGD Program

Major Energy Storage Demonstration Programs

- Tehachapi Storage Project (TSP)
- Irvine Smart Grid Demonstration (ISGD)

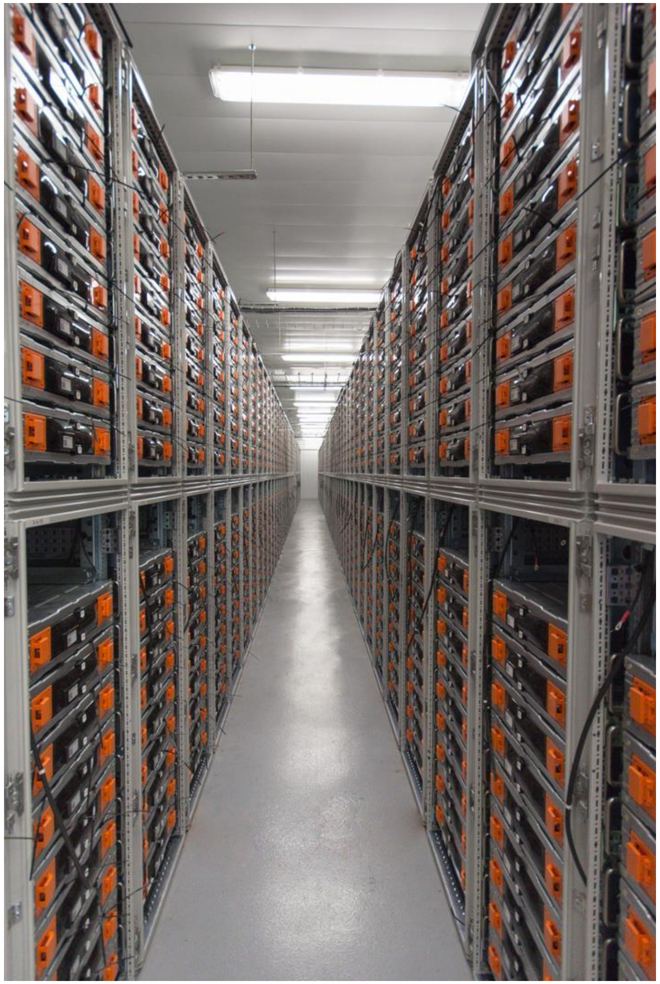
TSP

TSP Facility

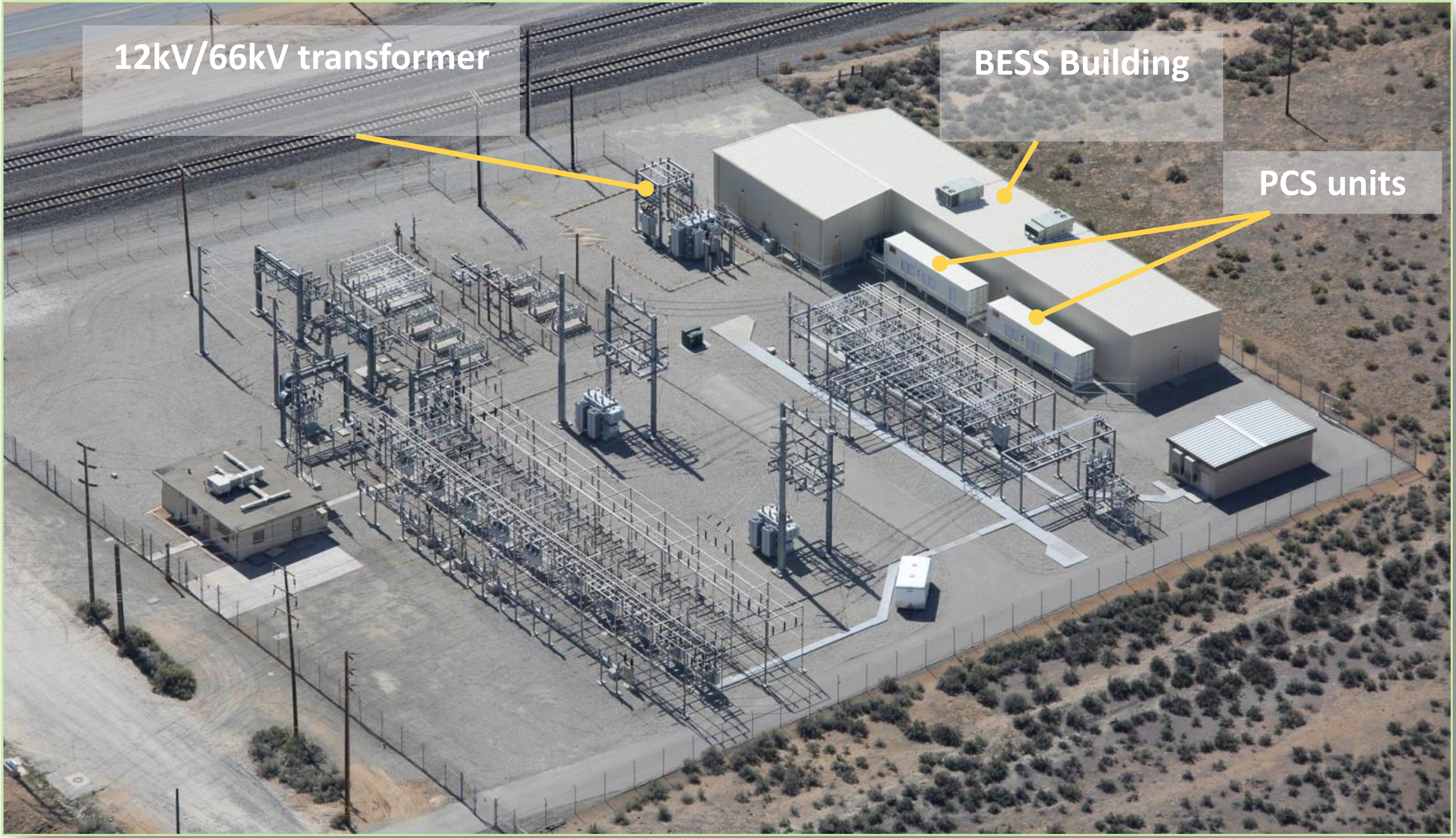
- Located in the Tehachapi area, California's largest wind resource
- Massive wind development potential (up to 4,500MW) driving grid infrastructure
- Installed at SCE's Monolith Substation
- 6,300 ft^2 building
- Connected at sub-transmission level through a 12/66kV transformer

System Specifications

- Battery Storage System
  - Li-ion
  - 32MWh usable
  - Manufactured by LG Chem.
- Power Conversion System
  - 9MVA
  - 12kV connected
  - Manufactured by ABB



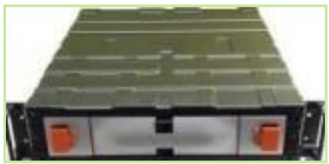
TSP Layout



System Configuration

How to get 32MWh from 60Wh battery cells

x 56



x 18

x 151

x 4

	Cell	Module	Rack	Section	System
Quantity	608,832	10,872	604	4	1
Voltage	3.7 V	52 V	930 V	930 V	930 V
Energy	60 Wh	3.2 kWh	58 kWh	8.7 MWh	32 MWh (AC)
Weight	380 g	40 kg	950 kg	N/A	N/A

Construction

- Dealt with challenges of a remote area
- Site constraints with local railroad tracks, high pressure gas lines, substation
- Very limited storage space
- Many "non-battery" tasks
- Windy weather
- Rodents and insects




Commissioning

- Project team members collaborated closely to develop the commissioning plan
- Plan involved several iterations of reviews and revisions
- PCS controls, Battery and overall system controls, and IT components were commissioned in parallel whenever possible
- June 2014: BESS delivered 32 MWh during initial commissioning tests
- September 2014: Grand Opening Ceremony

System Validation Challenges

- Large energy storage systems are modular
  - Comprised of AC and DC subsystems
  - Scaled by adding additional components in series/parallel
  - Multiple manufacturers
  - Requires complex integration
  - Increased likelihood of problems
- Utilities need to assess safety and reliability prior to field deployment
- Issues with testing large systems in the field
  - Grid/personnel safety
  - Geographic distance
  - Need to exchange significant power at will
  - Hardware/firmware/software problems can take many months to solve

System Validation Approach: Mini-System Lab Testing

Mini-System enables subscale testing in the lab before full-scale operation of the BESS at Monolith Substation

	Mini-System	Full System
Footprint	77 ft^2	6300 ft^2 building
Power	30 kW	8 MW
Energy	116 kWh	32 MWh
Power Conversion System	One Mini-Cabinet	Two 40-foot containers
Sections	1	4
Banks	1	32
Racks	2	604
Modules	36	10,872
Cells	2,016	608,832

Mini-System for Sub-scale Testing

Mini System at SCE laboratory

Mini System at SCE laboratory (cont.)

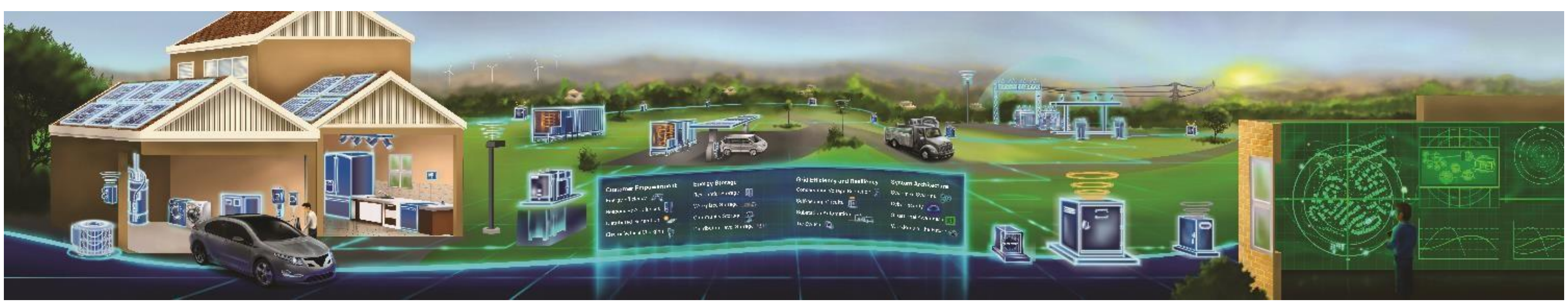
Mini-System Testing Key Findings

Key Findings	Benefits
Discovered and resolved critical safety and operational aspects regarding the battery system and PCS	Minimum impact of safety and operational issues, quick to resolve
Several iterations of software/firmware upgrades required	Significant time and resources saved due to upgrades performed in the lab at subscale level versus full-scale at remote substation location
24/7 operation for more than 4 months prior to full system commissioning yielded feedback to implement many additional functional upgrades	System operation and features have been enhanced (optimized control algorithms)

TSP - Final Thoughts

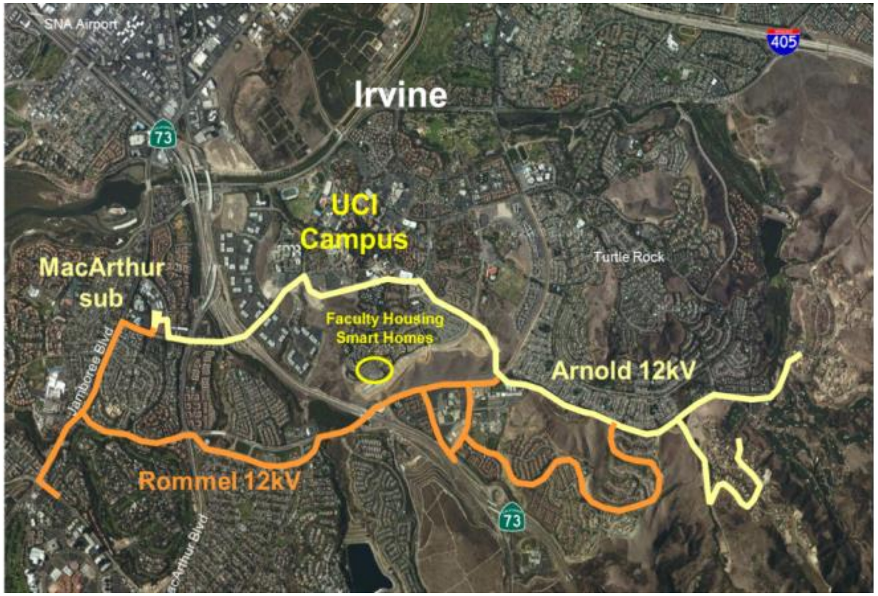
- Installation, deployment and preliminary operation of large-scale ESS has:
  - Provided key learning to facilitate future deployments
  - Demonstrated the benefits of Mini-System testing
- Close collaboration between utility and turnkey system provider has accelerated lessons learned

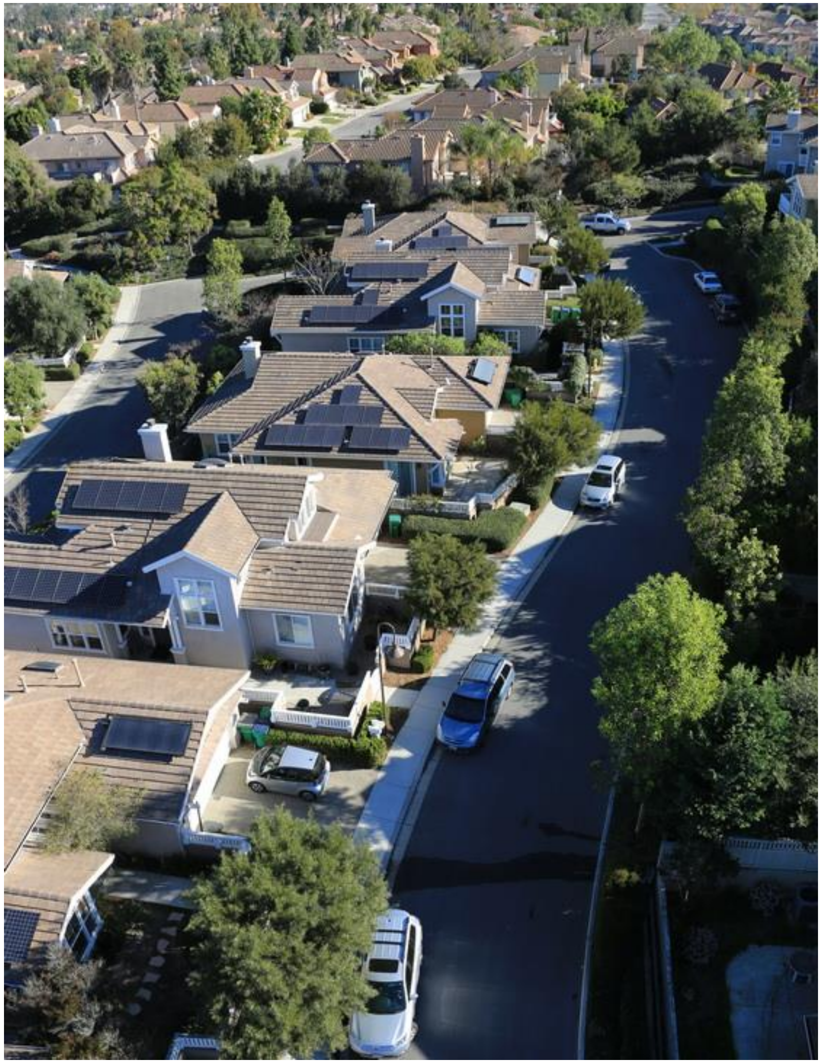
ISGD



ISGD Project Location

The Irvine Smart Grid Demonstration (ISGD) is hosted on the University of California, Irvine campus and at the MacArthur Substation in Newport Beach, California.





ISGD Project Domains

Smart Energy Customer Solutions

- Zero Net Energy (ZNE) Homes through Smart Grid Technologies including:
  - Residential Storage
  - Community Storage
- Solar Shade-enabled Electric Vehicle Charging coupled with Storage System

Next Generation Distribution System

- Distribution Circuit Constraint Management with Energy Storage
- Distribution Volt/VAR Control
- Self-Healing Distribution Circuits
- Deep Grid Situational Awareness

Interoperability & Cybersecurity

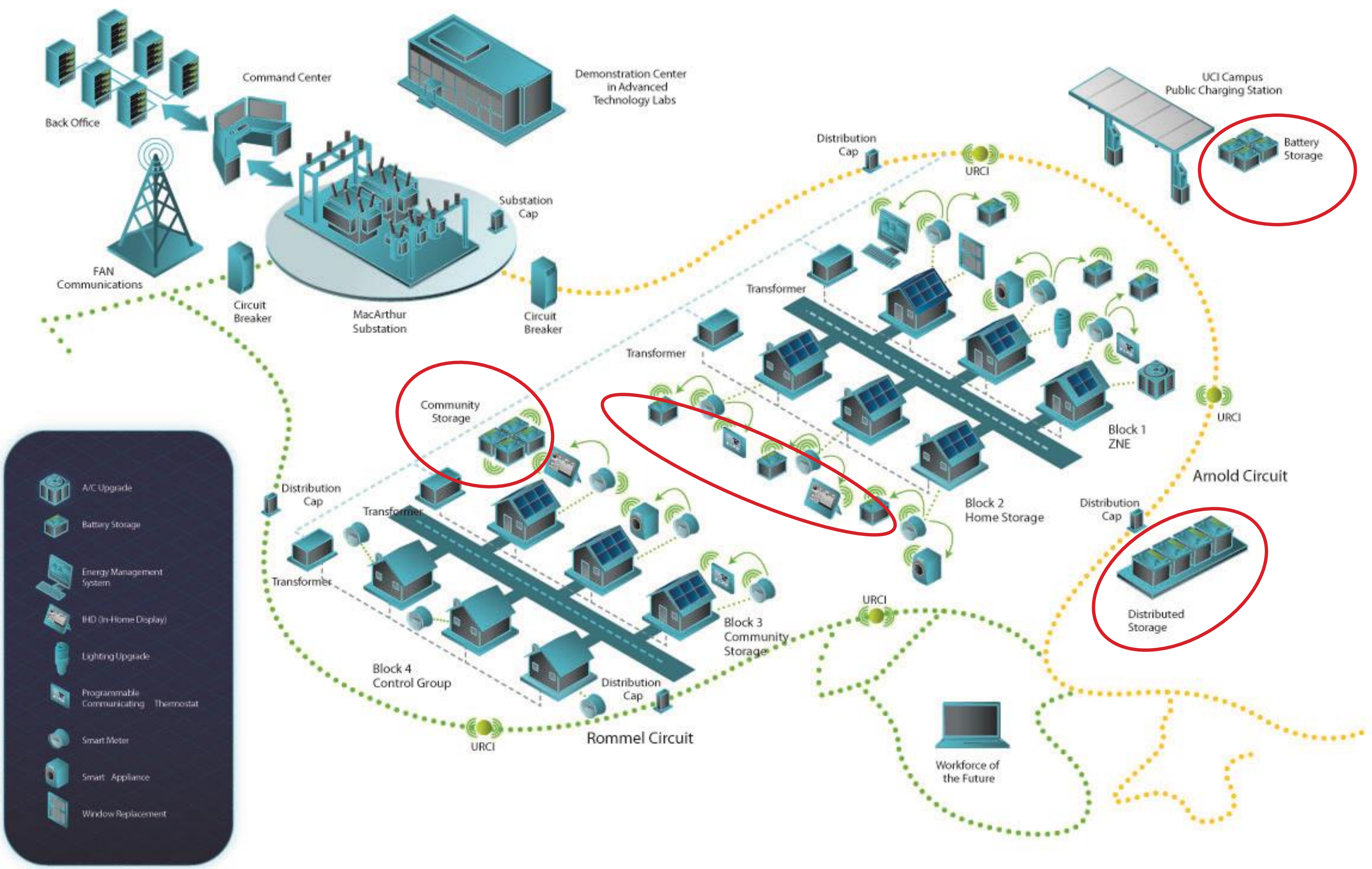
- Secure Energy Network (SENet)
- SA-3 Substation Automation System

Workforce of the Future

- Workforce of the Future

ISGD Scope

Storage elements



ISGD Storage Elements

- Residential Energy Storage Unit (RESU)
  - 4kW / 10kWh
  - Installed in 13 homes
- Community Energy Storage (CES)
  - 25kW / 50kWh
  - 1 device serving 9 homes
- Electric Vehicle Charging Station with PV and Storage (BESS)
  - 100kW / 100 kWh
  - Paired with 20 EV charging stations & 48 kW PV array
- Large Distributed Energy Storage System (DBESS)
  - 2 MW / 500kWh
  - Connected to a 12 kV distribution circuit

Storage Elements


Residential Energy Storage


Community Energy Storage


EV Charging Station


Distributed Energy Storage System

Safety Considerations

- All system were thoroughly evaluated in the laboratory before field deployment to:
  - Validate system safety behaviors (e.g., system shutdown on abnormal conditions)
  - Validate all modes of operation
  - Characterize system performance
  - Assess grid impact
  - Perform short reliability evaluation

Residential Energy Storage Unit (RESU)

- Objective:
  - Understand the impact, use cases, and characterize performance of Residential Energy Storage
- ISGD Experiments Conducted:
  - Peak Load Shaving (level and cap demand)
  - Demand Response
  - Critical Load Backup
  - Reactive Power (VAR) Support

RESU – Safety Consideration

- Garage installation required safety brace to protect against vehicle collisions
- Immature platforms requires close monitoring
- RESUs experienced multiple issues in the field that required on-site visits to resolve:
  - Software failures
  - System lockups that could cause battery over discharge. New software versions introduced fixes to improve reliability.
- Hardware failures
  - Touch screen display failures
  - One battery fault resulting in a cell voltages. Programmed safety limits worked as intended preventing system failure.

Community Energy Storage (CES)

- Objective:
  - Assess the value of highly distributed storage system (one storage unit per distribution transformer)
- ISGD Experiments Conducted:
  - Peak Load Shaving (level and cap demand)
  - Islanding
  - Reactive Power (VAR) Support

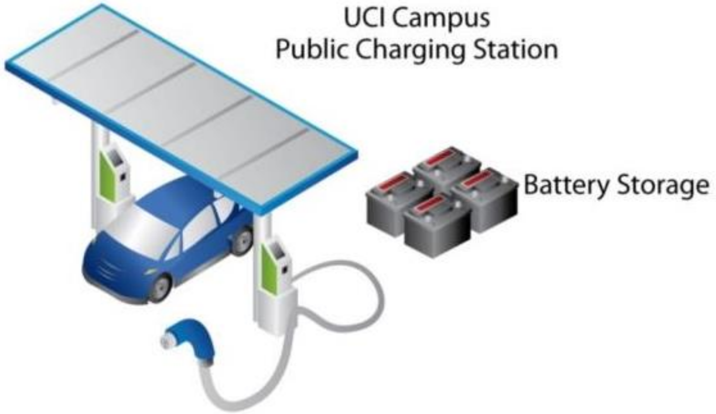
CES Installation

Control systems and transformer located above ground. Battery installed underground. The CES has nominal continuous power output rating of 25 kVA and usable stored energy of 50 kWh.

CES – Other Consideration

- Installation was more complex than anticipated (reinforced vault due to road close-proximity)
- Installed a full bypass system to allow quick power restoration in the event of a system failure
- System noise level was noticeable, particularly at night

Solar Car Shade BESS



- Objectives: Combine a PV system with energy storage in order to charge PEVs, while mitigating or eliminating any associated incremental system peak load
- Challenges:
  - Immaturity of the system integration (several software updates required)
  - Control system limitations

Distributed Battery Energy Storage System (DBESS)

- Objectives
  - Leverage a large energy storage device connected to a distribution circuit to provide:
    - circuit constraint relief
    - getaway overload condition relief
  - Support additional sub-projects by injecting or withdrawing power from the circuit
- Deployment Challenges
  - Permitting and licensing
  - Cost of installing equipment, including required transformers & cooling system

Storage System & Balance of Plant

Conclusion - Lessons Learned & Challenges

- Availability of truly grid-ready integrated systems
  - Storage system may be mature, integration into complete turn-key system is not
- Siting, Siting, Siting
  - Site selection, aesthetics, noise
- Demonstrating reliability at the system level
- Capturing promised value streams in actual applications & building positive business cases
- Integrating with existing utility communication infrastructure & new Smart Grid technologies
- Validating large systems prior to deployment
- Availability of standard application definitions and test procedures

THANK YOU